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## **Homeodynamics, Shape and Motion dynamics in Self-Moving Oil Droplets**

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We have developed a simple chemical system capable of self-movement in order to study the chemical-molecular origins of movement, perception and cognition (Hanczyc et al. 2007, Toyota et al., 2009). The system consists simply of an oil droplet in an aqueous environment. The aqueous phase contains a surfactant that modulates the interfacial tension between the drop of oil and its environment. We embed a chemical reaction in the oil phase that reacts with water when an oily precursor comes in contact with the water phase at the liquid-liquid interface. This reaction not only powers the droplet to move in the aqueous phase but also allows for sustained movement. The direction of the movement is governed by a self-generated pH gradient that surrounds the droplet. In addition this self-generated gradient can be overridden by an externally imposed pH gradient, and therefore the direction of droplet motion may be controlled. Also we noticed that convection flow is generated inside the oil droplet to cause the movement, which was also confirmed by simulating the fluid dynamics integrated with chemical reactions (Matsuno et al. 2007).

We believe that the geometry of the interface shape can control sensitivity to the environment (Suzuki and Ikegami, 2009, Ikegami and Suzuki 2009). This geometry-induced fluctuation is the source of fluctuation of motion, which we think is tightly linked with the idea of biological autonomy.

There is empirical evidence to support the above ideas. For example, it has been found that by pushing the cytoplasm of a cell, one can elicit a directional locomotion. The asymmetrical change of a boundary shape causes polarization of actin and myosin protein fragments, and their interaction causes a straight forward motion. This internal polarization of biological chemicals is similar to our observation. In both cases, some form of internal bias is necessary for breaking symmetry to cause self-movement and the bias may be the result of perception of the environment.

In this presentation, we will report the size dependency of the droplet motion. It was demonstrated that the shape of the droplet changes at a certain point as we increase the size from a few  $\mu$  meters to a few centi-meters, and accordingly the motion pattern changes from Brownian-like to marching.

The previous our chemical experiments and the numerical simulations sug-

gest that the mechanism of the self-movement is caused by the convection flow coupled with the chemical reaction. But when we increase the size of the droplet, the convection becomes more disordered and the boundary of the droplet becomes wilder. We discuss the phenomena more in detail and propose a new design principle for chemical locomotion and the associated chemical intelligence (e.g. sensing the chemical gradient, coupling with the other droplets).

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## **A method for constructing databases of global dynamics of multi-parameter systems**

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A computational method for constructing a database of global dynamics of a multi-parameter dynamical system is introduced. An outer approximation of the dynamics for each subset of the parameter range is computed using rigorous numerical methods and is represented by means of a directed graph. The dynamics is then decomposed into the recurrent and gradient-like parts by fast combinatorial algorithms and is classified via the so-called Morse decompositions. These Morse decompositions are compared at adjacent parameter sets via continuation to detect possible changes in the dynamics. The Conley index is used to study the dynamics of isolated invariant sets associated